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SPECIAL DESIGN FEATURES OF WATER WORKS FACILITIES HANDLING HIGHLY TURBID WATERS

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SPECIAL DESIGN FEATURES OF WATER WORKS FACILITIES HANDLING HIGHLY TURBID WATERS

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To most of us in the water works field the expression "treatment of highly turbid waters" immediately suggests the "Big Muddy" or Missouri River as the source of supply. This paper deals with the problems involved in transforming water of the wild Missouri into a sparkling finished product conforming to all of the present rigid standards of quality.

Missouri River Drainage Basin

The Missouri is the longest river in North America and drains about one-sixth of the United States. Its broad extent is shown in Figure 1. Parts or all of the states of Colorado, Iowa, Kansas, Minnesota, Missouri, Montana, Nebraska, North Dakota, South Dakota, and Wyoming are contained within the drainage basin.

The shaded area indicated in Figure 1 is known as the Lower Missouri Drainage Basin. Treatment problems encountered in this area will receive primary consideration in this discussion. The Lower Missouri River is the source of supply for 16 municipalities representing a population of almost 2,000,000 people with an average annual daily use of over 250 million gallons. The quantity of Missouri River water passing through industrial plants including that used by power plants for circulating water exceeds one billion gallons per day.

Water Treatment Problems

The removal of silt and other suspended matter from the raw river water constitutes the primary treatment problem. It is believed by many that the large impounding reservoirs being constructed on the Upper Missouri will greatly alleviate the problem of removing settleable material. By referring to Figure 1 it will be observed that these reservoirs are situated on the main stem of the Missouri as far downstream as Yankton, South Dakota. The Fort Randall and Gavins Point reservoirs are now in operation. It was reported during the latter part of August (1953) that substantially clear water was observed for a distance of eighty miles below Yankton. This is to be expected in view of the abnormally low rainfall in that area. While it is yet too soon to draw definite conclusions it appears fairly certain that notwithstanding the effect of these reservoirs, the treatment plants located on the Missouri below Sioux City will always be confronted with the problem of treating highly turbid waters. Although doubtless the total tonnage of silt removed annually by treatment plants will be very materially reduced, nevertheless it is to be expected that runoff from drainage areas below Yankton will create flashy turbidity problems.

Another treatment problem which may become more persistent and complex because of the upstream reservoirs is the control of tastes and odors. In the past, conditions causing tastes and odors occurred usually during winter and early spring and have not been too difficult to handle. However, it appears possible that the reduction of turbidity in the storage reservoirs may permit the production of plankton organisms resulting in more serious taste and odor problems at the water plants downstream.

The problem of pollution of the Missouri River water supply is a matter of utmost concern. While water treatment plants in the Lower Missouri Basin are producing potable water which is safe bacteriologically, the coliform trend is definitely upward. Records taken at Kansas City, Kansas since 1922 indicate this trend:

Year	Average Annual Coliform M.P.N. per 100 ml
1922	6,000
1923	6,500
1924	16,500
1925	22,000
1930	18,400
1935	19,400
1940	29,100
1945	38,400
1950	57,000
1952	75,100

NOTE: Water containing more than 20,000 coliform bacteria per 100 ml does not meet drinking water standards and is generally considered undesirable as a source of supply.

It is most fortunate that the art of water treatment has advanced as the degree of pollution has increased. While the water works engineer is certainly concerned with these continued advances, he is equally concerned with ways and means of reducing pollution at its source in order that the quality of the raw water can be controlled within safe and conservative limits. The subject of treatment of sewage and industrial wastes in the Lower Missouri Basin has already been given thorough study by the U. S. Public Health Service working in conjunction with the Boards of Health of the various states involved. However, no treatment plants have yet been built along the Lower Missouri.

The chemical quality of Missouri River water falls within acceptable limits as compared with many other streams in the Mississippi Valley subject to industrial pollution, such as the Arkansas and Ohio. However, since the hardness varies markedly during the year many cities are now softening Missouri River water. For example, at Council Bluffs, Iowa the hardness of the river water varies from a low in the summer months of about 135 ppm to readings higher than 400 ppm during the months of December, January, and February when the river stage is lowest. The recently completed softening plant at that city is now producing a finished water ranging in hardness between 85 and 100 ppm.

The major water treatment problems encountered along the Lower Missouri may be summarized briefly as including: (1) removal of turbidity ranging as high as 30,000 ppm; (2) taste and odor control which may soon become seriously

aggravated by storage reservoirs located on the upper Missouri; (3) the definitely upward trend in coliform index caused by the ever increasing discharge into the river of untreated sewage and organic industrial wastes; (4) removal of hardness to a standard of 85 to 100 ppm.

Range and Duration of Turbidities

Of these four major treatment problems the water plant facilities involved in the handling and treatment of highly turbid waters will receive primary attention in this paper. The discussion will be confined largely to treatment plants at the following cities: Omaha, Nebraska; Council Bluffs, Iowa; Kansas City, Kansas; Kansas City, Missouri.

The 1953 maximum day demands on these plants amounted to a total of 280 mgd, as follows: Omaha - 93 mgd, Council Bluffs - 8 mgd, Kansas City, Kansas - 44 mgd, and Kansas City, Missouri - 135 mgd.

Table I is included to demonstrate the wide range in turbidity experienced at Omaha. Maximum and minimum readings are shown by months for the period 1937 through July 1953. During the winter months the turbidity drops as low as 15 but during the spring and early summer turbidities as high as 32,000 have been recorded. Turbidity readings at the Council Bluffs, Iowa water plant located about 7-1/2 miles downstream from the Omaha plant are usually somewhat lower than those observed at Omaha. The reason for this is believed to be that the Omaha intake is located on a rock ledge at a relatively sharp bend in the river while the Council Bluffs intake is located on a wide bend where the river bottom is free to scour. Maximum annual turbidities observed at the Kansas City, Missouri plant are also indicated in Table I for the years 1941 to 1952. Readings in excess of 20,000 ppm have been observed at Kansas City.

Table II shows the duration in turbidity at Kansas City, Missouri for various ranges from less than 200 ppm to over 8,000 ppm for the ten-year period 1944 to 1953.

By referring to the 1953 turbidity readings at Omaha and Kansas City (as indicated in Table I and Table II) it will be noted that they are materially below average values. This trend is no doubt due in part to the fact that the Fort Randall and Gavins Point reservoirs have been in operation during the current year. It is believed, however, that the abnormally low rainfall during 1953 in the Lower Missouri Basin has also played a large part in reducing turbidity observations below normal.

In the treatment of highly turbid waters such as that of the Missouri River it is essential that the raw water be passed through presedimentation basins before the initial application of chemicals. Substantial economies can be effected in this manner since a very large percentage of the suspended solids can be removed without the use of chemical treatment. Presettling of the raw river water also smooths out the irregularities in the turbidity of the water at the point of chemical application. In effect presedimentation basins act as a shock absorber on the succeeding plant units and eliminate to a very great degree the necessity of frequent changes in chemical application due to the fact that the suspended solids content of the presedimentation basin effluent is relatively constant.

Historical Aspects of Water Treatment Plants on Lower Missouri

The present modern water treatment plant handling highly turbid Missouri River water represents a vast improvement over the original plant which

included settling basins only. Table III indicates the historical development of the four plants under consideration.

In the case of the Council Bluffs plant it will be observed that only settling basins were used prior to 1952 when a complete new softening plant was placed in operation. The old plant consisted of two presedimentation basins, five coagulation basins and three clear water basins, the total capacity of which was equal to about one full week's storage on maximum days. This extremely large amount of storage accounts for the fact that this plant was capable of producing a safe finished water without the use of sludge removal equipment or filters.

Use of the old type presedimentation basin is being discontinued generally. Since these old units were not provided with continuous sludge removal equipment they became filled with sediment rapidly which largely nullified their intended function. This type basin must be taken out of service frequently and the huge deposition of sediment removed laborously by flusing through mud valves with high pressure fire hose.

Perhaps the tonnage of mud and sand to be removed from these basins will be visualized more clearly by the following examples: (1) For a basin detention period of three hours the amount of sediment contained in Missouri River water having a turbidity of 20,000 ppm would be sufficient to completely fill the basin in about ten days; (2) the tonnage removed for a raw water rate of 100 mgd and turbidity of 20,000 ppm is estimated to be about 8,000 tons per day, or equivalent to 160-50 ton railroad cars.

The reduction of turbidity in modern type presedimentation basins as compared to that in the original type basin is illustrated in Table IV for the Kansas City, Kansas plant. The original basins consisted of three narrow roughing units operating in parallel followed by a single presedimentation basin. The reason for the turbidity of the effluent exceeding 3,000 ppm on numerous occasions was due to the fact that the roughing basins soon became almost completely filled with sediment, thus throwing the entire turbidity load on the single basin. Short circuiting across this basin also aggravated the situation. Figure 2 is a photograph of the two new presedimentation basins. These basins are identical and are operated in parallel. They are 190 feet in diameter with a side water depth of 20 feet. The detention period is four hours at a peak design rate of 60 mgd. As indicated in Table IV the highest turbidity of the basin effluent on days of maximum turbidity was 520 ppm. At no time since these basins were placed in operation has the turbidity of the effluent exceeded 600 ppm. It is expected that it will be possible to maintain this turbidity substantially below 1000 ppm even when the basins are operating at peak design capacity. Provision has been made for the addition of a coagulant ahead of these basins if and when needed. This feature is considered advisable since an unusually difficult light weight turbidity is quite frequently encountered during the early spring runoff. By referring to Table IV it will be noted that during February 1948 the maximum raw water turbidity reading was 8,080 ppm and the basin effluent reading was 3,875 ppm. On other days during this particular period plain sedimentation affected practically no reduction in turbidity. The addition of a coagulant ahead of the presedimentation basins in such cases has been found to be very beneficial, since in effect three stage treatment is made available to combat a very difficult turbidity situation.

Flow Diagram for Hypothetical Softening Plant Treating Missouri River Water

Figure 3 illustrates the facilities considered necessary in a modern conventional water softening plant designed to handle Missouri River water. Since this paper deals primarily with those plant units preceding the first stage treatment, discussion of the remaining facilities will be very brief. If should be pointed out that the use of "suspended solids contact" type units is believed to be entirely feasible as an alternate to the conventional type plant units indicated. However, if such facilities are used, it is considered most necessary that the turbidity of the water entering these units be positively controlled and limited to a relatively uniform low value, preferably less than 1000 ppm. Furthermore, it is deemed advisable to design such a plant on a much more conservative basis than is normally acceptable for a supply of uniform characteristics such as a well supply.

Except in the case of a completely new plant, it is usually necessary to deviate quite materially from the ideal arrangement of plant facilities in order to make the best use of existing plant units. Nevertheless, in modernizing any water plant a very serious attempt should be made to approach the ideal layout as closely as possible, even if it becomes necessary to abandon completely or to overbuild portions of the existing plant. This is especially true in the design of the settling basins where it is very essential that proper overflow rates and weir rates be provided.

In plants treating Missouri River water without softening, such as the Kansas City, Kansas plant, units 3, 7, and 11 may be omitted from the flow diagram. In this case, prechlorine treatment would be applied to the second rapid mix (8). This practice permits an appreciable saving in chlorine because the turbidity is lowered from about 300 to 400 ppm to less than 10 ppm between the first and second rapid mix (4 and 8). In addition, the chlorine loss from units 5 and 6 is also eliminated.

Special Design Features of Raw Water Facilities

In considering a water treatment plant handling highly turbid waters such as the Missouri River supply as contrasted with a plant treating a water of low turbidity, special emphasis should be placed upon those facilities required between the river and beginning of second stage treatment or between units 1 and 7, as indicated in Figure 3. Reference is made specifically to (1) river intake, (2) raw water pumps, (3) raw water lines, (4) presedimentation basins, and (5) first stage treatment.

1) River Intake:

The intake should be situated on the outside bank of a long sweeping bend in the river in order to insure water at the intake at all river stages. At such a location the channel will not shift and will remain clear of sand bars. It is essential that low velocities, preferably less than two feet per second, be maintained through the net area of the bar screens as well as through the traveling screens. Provisions for the removal of mud and sand from the intake cells should be provided by installing suitable ejectors.

(2) Raw Water Pumps:

The present trend in raw water pumps is toward the use of vertical units located in a combined intake and pumping station structure. This type of pump requires much less space than is necessary for horizontal centrifugal pumps

located in a dry pit and usually in a structure separated from the intake. Another very important consideration is that pump motors for vertical units are safe against flooding hazards (from pipe breaks, etc.) that are always present in the case of pit installations. It is very essential that pump speed be held to the lowest practicable rate in order to prevent rapid erosion of rotating elements when pumping water containing sand and silt. At best pump maintenance costs are relatively high.

(3) Raw Water Lines:

It is necessary to maintain velocities of 3.5 to 5.0 feet per second in raw water pump discharge lines in order to prevent deposition of silt. In cases where pipe lines are oversize because of future design requirements, it is very desirable to provide means for periodically increasing the normal velocity sufficiently to scour out deposited silt. Special consideration should be given to the design of vertical runs of pipe to prevent the possibility of clogging. This applies in particular to the arrangement of influent piping to center feed type presedimentation basins.

(4) Presedimentation Basins:

Considerable discussion has already been presented on the past history of presedimentation facilities. Operating results for the recently completed basins at the Kansas City, Kansas plant are presented in Table IV, while Figure 2 is a photograph of these basins. At the Kansas City, Missouri plant two additional basins 200 feet in diameter with a side water depth of 20 feet are now under construction. These basins will be quite similar in appearance to the Kansas City, Kansas units. The principal difference will be in the arrangement of the center feed well. By referring to Figure 2, it will be observed that the incoming water is released vertically inside of an open circular steel baffle. It is unnecessary to consider ice troubles in these basins since all water used at this water plant first passes through condensers at the power station. As a result the temperature of the water reaching the water plant never falls below 40 to 45^{o}F.

At Kansas City, Missouri provision is being made for a stationary steel hood 25 feet in diameter to enclose completely the rotating feed element. The hood will act as a baffle ring in addition to protecting the rotating portion from ice difficulties. The usual feed well arrangement has been modified and expanded to provide a quick mixing type distributor. Softening sludge from the primary basins will be returned to this feed well for disposal along with the normal blowoff of sediment. In addition to the disposal of sludge it has been demonstrated that this sludge is quite beneficial in reducing turbidity in the presedimentation basins. Provision will also be made for the application of a coagulant at the feed well if and when necessary to control turbidity within desired limits.

Sludge lines from the presedimentation basins should be provided so that a wide range in the rate of blowoff is possible, hence it is advisable to install no less than two lines of graduated sizes in order that scouring velocities may be maintained for any desired rate.

The capacity of the sludge lines should be sufficient to permit a rate of blowoff equal to 25% to 30% of the incoming raw water rate. The sludge removal equipment in the case of the Kansas City, Missouri units is designed to remove sludge at the rate of 175 tons per hour per basin.

(5) First Stage Treatment:

Figure 4 is a photograph of a portion of the Kansas City, Kansas plant showing the new primary flocculation and settling basins in the foreground; the

converted final basins in the immediate background; the abandoned basins, the present filter plant, and the power station in the extreme background. (The presedimentation basins are out of the picture to the right). When all proposed improvements are completed, a new filter plant, head house, and clear water storage reservoir will replace the abandoned basins.

The new primary flocculation and settling basins could not be arranged symmetrically because of site limitations. This fact made it all the more essential that water entering the flocculation basins be distributed uniformly and also that necessary provisions be made to prevent short circuiting. One-half of the water being treated is delivered through each of two separate conduits extending from the first rapid mix chambers to a rising well located at the midpoint of each flocculator basin. These rising wells affect a 50-50 split, thus dividing the total flow into four equal parts. Each of these four parts is further divided three ways. The flow distribution facilities designed to accomplish this final division are shown in Figure 5. It will be observed that two adjustable steel fins are provided; the first of which is regulated to intercept one third of the flow, and the second to divide the remaining flow into two equal parts. Thus the total flow is divided into 12 equal portions after which each is directed downward into the flocculation basins between training walls which are designed to eliminate any possibility of short circuiting.

Baffle walls with bottom ports are located normal to these training walls and between rows of flocculator paddles. Water leaving each flocculator basin is introduced at the mid point of one side of each settling basin through a wide baffled port arranged to diffuse the flow without effecting the quality of the floc. Settling basin effluent is collected in U-shaped launders which extend along one side and both ends of each basin. As previously stated, since the new presedimentation basins have been placed in operation the highest turbidity water reaching the first rapid mix has been somewhat less than 600 ppm. The effluent from the primary settling basins has a turbidity of about 10 ppm. Hence, the turbidity problem vanishes from the picture in the first stage treatment.

General Comments Relative to Complete Treatment Process

While special emphasis has been placed in this paper upon those facilities located between the river and the beginning of the second stage treatment it is believed that a few additional comments pertaining to the complete treatment process should be included. By referring to the flow diagram (Figure 3) it will be observed that second stage treatment followed by secondary CO_2 application, filtration, and post chlorination (as required to supplement prechlorination) is considered necessary in any plant designed to treat and soften Missouri River water.

In the matter of sludge handling and disposal it is essential that certain specific facilities be provided, as follows: (1) Necessary facilities should be provided to permit primary sludge to be wasted directly to the river or returned either to the presedimentation basins or to the second rapid mix; (2) provision should be included to waste secondary sludge or return it to the second rapid mix. It is considered desirable to deliver substantially stable water to the filters in order to prevent rapid build up of the filter sand and what is more essential to assure long filter runs. The use of returned sludge has proven very beneficial in this respect.

While a filtration rate of three gallons per square foot per minute (150% rating) is indicated and is considered sound practise the filter piping should be designed hydraulically for not less than 200% rating for reserve or emergency capacity.

It is fundamental that sufficient clear water storage capacity should be provided at the plant and on the distribution system to permit the rate of flow through the plant to be held substantially constant during any 24-hour period.

As a concluding statement, it may be well to recall that the Missouri River has often been referred to as "too thick to navigate and too thin to cultivate." But the "Big Muddy" does contain a very important element known as water which in itself is pure and sparkling and constitutes the life stream of those metropolitan areas that have developed along its course.

References

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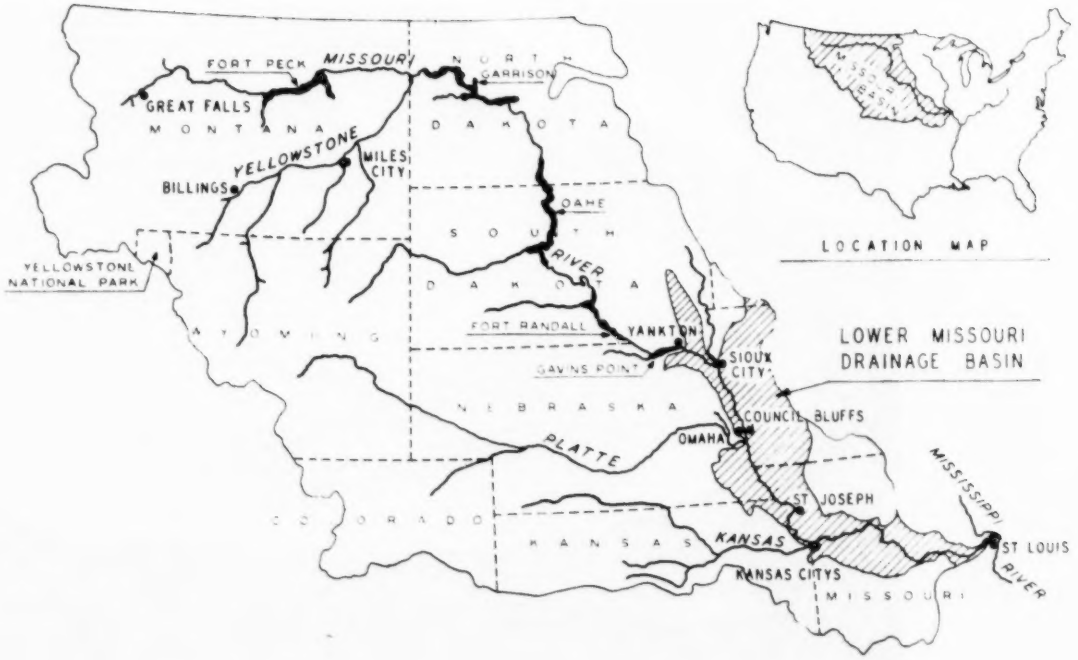
   Water Pollution Investigation
   U. S. Public Health Service
   October 1952

2. Operating Data from Water Departments:

   Omaha, Nebraska
   Council Bluffs, Iowa
   Kansas City, Kansas
   Kansas City, Missouri



MISSOURI DRAINAGE BASIN

FIG NO 1

PRESEDIMENTATION BASINS - KANSAS CITY, KANSAS

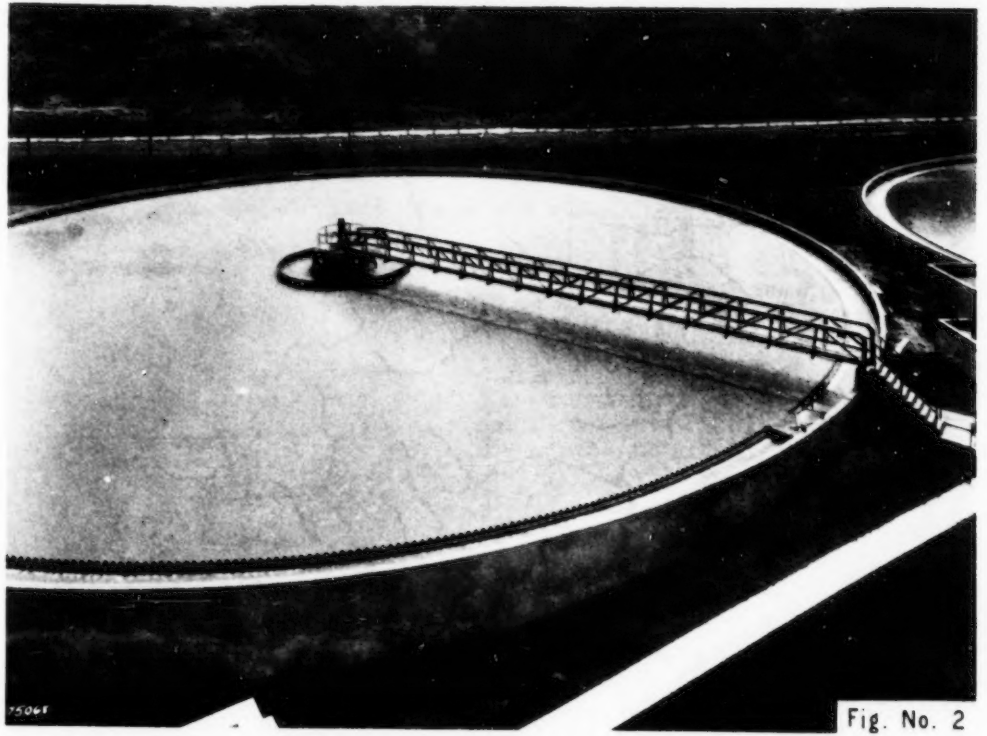
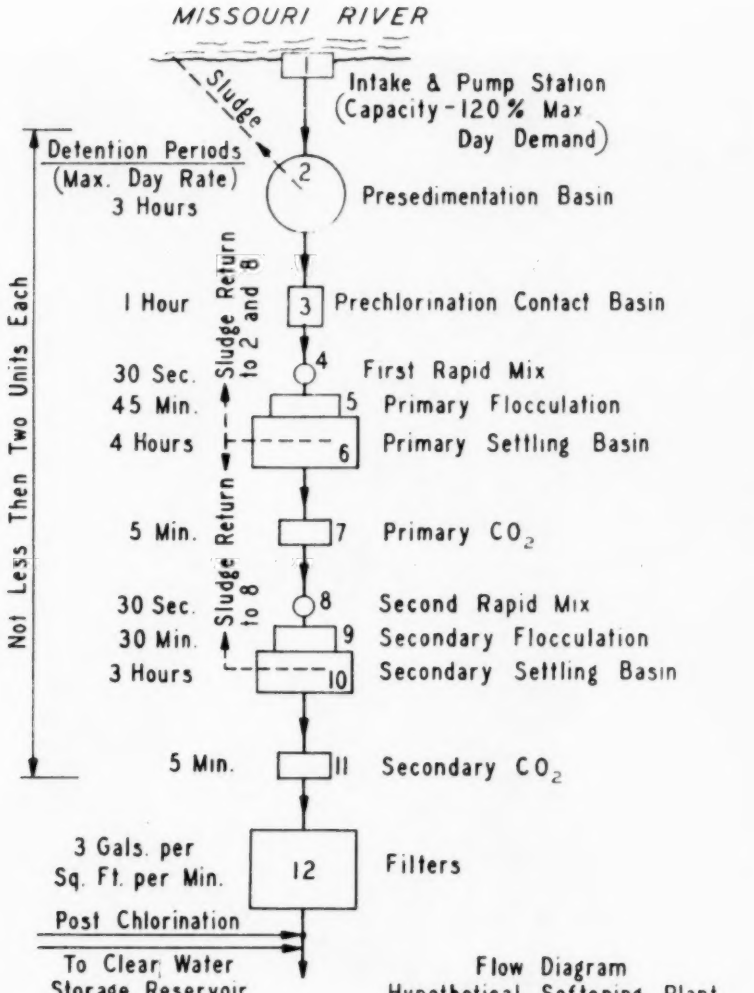


Fig. No. 2



Flow Diagram
Hypothetical Softening Plant
Treating Missouri River Water

Fig No 3

FLOCCULATION & SETTLING BASINS - KANSAS CITY, KANSAS

Fig. No. 4

FLOW DISTRIBUTION FACILITIES - KANSAS CITY, KANSAS

Fig. No. 5

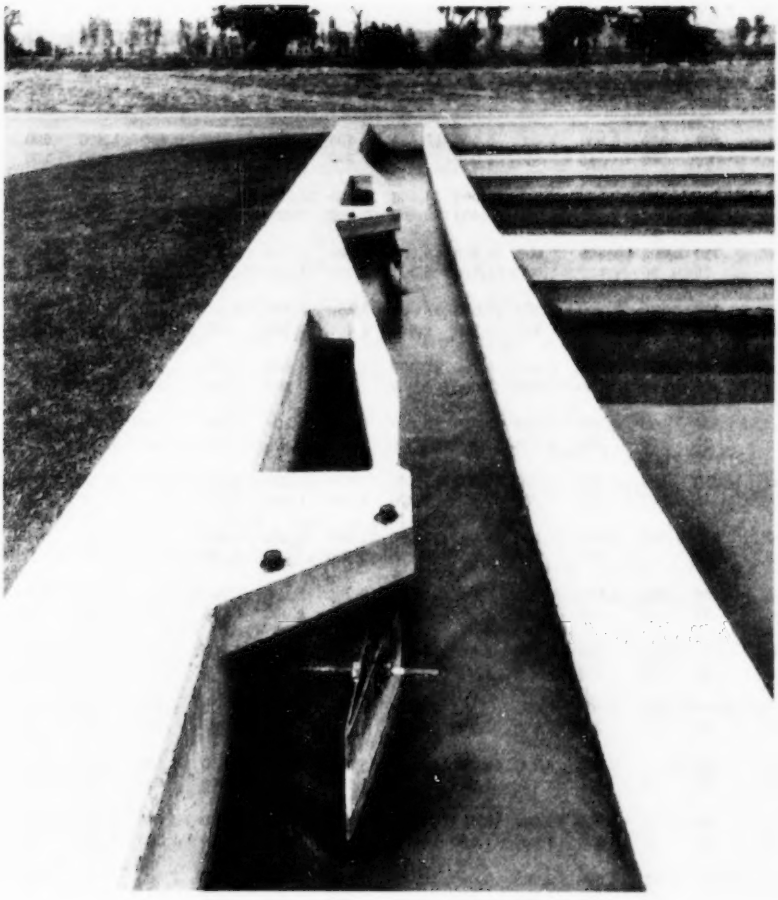


Table I

TURBIDITIES - MISSOURI RIVER AT OMAHA, NEBRASKA

		Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Maximum Turbidity at K. C., Mo.
1937	Max.	220	460	4,200	8,400	6,200	17,500	32,000	15,600	2,000	1,400	4,000	280	
	Min.	25	80	250	1,500	1,280	3,500	2,400	1,200	400	400	160	35	
1938	Max.	260	1,900	6,600	12,000	11,100	14,400	10,500	4,500	15,500	4,000	1,500	550	
	Min.	130	100	620	1,500	1,600	3,000	2,600	2,000	1,400	700	290	75	
1939	Max.	400	310	6,000	7,400	5,000	12,800	11,500	6,000	10,000	3,800	1,200	900	
	Min.	65	40	65	1,600	1,000	2,700	2,300	800	550	450	600	100	
1940	Max.	45	120	10,800	6,000	12,000	14,000	12,000	28,000	2,600	15,500	13,000	650	
	Min.	20	50	35	1,000	1,600	2,400	1,300	2,000	750	400	320	25	
1941	Max.	550	3,000	1,800	23,000	11,200	16,500	10,400	8,500	12,900	10,100	13,300	2,500	11,000
	Min.	25	30	130	1,000	1,800	3,200	1,200	1,000	2,700	1,800	550	110	
1942	Max.	250	190	6,200	8,700	27,000	13,000	7,800	4,700	2,800	2,300	2,000	700	12,600
	Min.	20	55	80	1,800	2,000	4,800	2,000	1,200	800	700	600	30	
1943	Max.	95	2,000	2,300	6,500	6,800	19,000	6,900	6,000	4,600	1,400	1,200	800	16,000
	Min.	25	25	100	1,800	1,000	2,100	2,000	900	1,300	950	700	30	
1944	Max.	800	1,800	5,000	7,500	10,400	13,500	8,800	6,300	4,800	900	1,800	700	20,000
	Min.	35	75	220	2,000	1,300	2,800	1,300	1,200	500	500	700	20	
1945	Max.	210	900	5,600	14,500	10,000	15,000	10,400	4,200	1,800	2,200	1,100	550	14,000
	Min.	15	55	230	700	500	1,700	2,000	1,400	700	1,000	160	20	
1946	Max.	270	1,300	2,400	2,400	27,000	20,000	11,500	6,000	6,000	6,000	3,300	700	16,000
	Min.	30	85	400	660	600	2,400	2,500	650	1,100	2,000	550	40	
1947	Max.	180	250	2,300	7,700	7,000	11,600	7,200	2,100	1,300	1,400	1,600	500	12,000
	Min.	25	35	250	2,600	1,400	2,800	1,600	1,000	1,000	1,000	400	45	
1948	Max.	230	8,000	5,000	4,600	8,000	8,000	8,400	7,200	4,400	2,000	2,000	800	11,500
	Min.	25	20	190	1,500	1,000	1,000	3,000	1,700	900	1,000	900	40	
1949	Max.	2,000	250	5,600	5,600	5,000	10,000	6,000	3,500	4,800	6,500	1,500	650	10,000
	Min.	35	40	220	1,100	1,000	1,400	1,000	700	700	700	600	50	
1950	Max.	110	1,500	6,200	7,200	14,000	15,000	7,500	6,000	6,300	4,000	1,500	210	12,500
	Min.	30	25	150	3,000	1,900	1,500	1,300	1,100	900	900	220	50	
1951	Max.	340	3,600	5,200	10,000	16,400	12,600	13,500	6,400	5,800	4,800	1,800	3,000	13,000
	Min.	85	65	170	2,000	1,100	2,400	1,200	1,000	1,200	1,300	1,000	45	
1952	Max.	1,000	1,500	5,500	6,000	7,000	10,000	21,000	1,500	1,300	1,000	800	250	15,000
	Min.	60	220	300	1,500	1,500	1,500	1,000	600	600	600	380	40	
1953	Max.	110	800	6,000	3,200	8,000	8,000	2,500						
	Min.	40	70	170	400	400	350	350						

Table II

RANGE IN MISSOURI RIVER WATER TURBIDITIES
AT KANSAS CITY, MISSOURI

The measure of river water turbidity for the last ten fiscal years is given by the following tabulation of time percentages related to ranges of turbidity:

Fiscal Year Ended Apr. 30th	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	Average
Turbidity less than 200 ppm	11.3%	10.4%	10.8%	13.9%	13.8%	11.2%	11.9%	15.3%	7.9%	12.3%	11.9%
Turbidity 201 to 500 ppm	5.2%	7.1%	8.6%	13.9%	9.1%	6.3%	12.2%	10.4%	7.4%	18.4%	9.9%
Turbidity 501 to 1000 ppm	30.8%	21.9%	18.1%	11.6%	16.5%	15.6%	24.8%	15.3%	13.9%	29.9%	19.8%
Turbidity 1001 to 2000 ppm	20.9%	16.2%	25.0%	17.0%	35.3%	30.1%	24.0%	17.0%	35.0%	19.2%	24.0%
Turbidity 2001 to 3000 ppm	10.5%	15.9%	10.3%	14.9%	12.4%	11.0%	9.4%	14.8%	14.2%	5.2%	11.9%
Turbidity 3001 to 4000 ppm	8.3%	8.8%	11.9%	7.7%	6.8%	13.4%	8.6%	12.1%	10.7%	4.9%	9.3%
Turbidity 4001 to 6000 ppm	8.5%	11.2%	9.4%	11.6%	2.8%	8.2%	6.6%	9.9%	7.7%	7.4%	8.3%
Turbidity 6001 to 8000 ppm	3.3%	4.7%	3.6%	5.0%	1.9%	3.4%	1.4%	2.7%	1.6%	0.8%	2.8%
Turbidity over 8000 ppm	1.2%	3.8%	2.3%	4.4%	1.4%	0.8%	1.1%	2.5%	1.6%	1.9%	2.1%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Maximum Turbidities Reported	16,000	20,000	14,000	16,000	12,000	11,500	10,000	12,500	13,000	15,000	

Table III

HISTORICAL DATA - DEVELOPMENT OF WATER TREATMENT PLANTS ON LOWER MISSOURI RIVER

	Omaha, Nebraska	Council Bluffs, Iowa	Kansas City, Kansas	Kansas City, Missouri
Date settling basins only were last used	1923	1952	1909	1928
Date filters were added	1923	1952	1909	1928
Date sludge removal equipment was added in presedimentation basins	Proposed for 1954	1952	1951	1928*
Date sludge removal equipment was added in primary settling basins	Proposed for 1955	1952	1951	1942
Date water softening was initiated	Proposed After 1955	1952	No Immediate Plans	1942

*Two additional modern basins to be placed in service in 1954; four original basins to be modernized in 1956.

Table IV

TURBIDITY REDUCTION IN PRESEDIMENTATION BASINS

(On Days of Maximum Turbidity)
Kansas City, Kansas

YEAR	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
(1) Operation Through Original Basins												
1948												
River	288	8080	7800	2980	4730	6280	8080	6880	4120	2050	2650	825
Basin Effluent	180	3875	3000	790	550	1000	880	1060	680	470	850	415
Rate in mgd	24.1	24.5	22.8	19.3	22.8	26.9	24.7	24.9	24.7	22.4	23.1	25.0
1949												
River	950	1190	3930	4270	4550	7920	4920	1870	3620	3370	830	480
Basin Effluent	410	690	1250	1330	730	1400	1070	530	830	420	270	300
Rate in mgd	19.1	24.9	24.6	23.6	25.4	30.8	29.2	28.0	27.3	23.8	25.1	23.1
1950												
River	310	1270	2520	5500	9830	8830	5930	5000	3200	6300	1200	430
Basin Effluent	250	770	1030	1500	3100	1380	1370	1380	540	1060	520	170
Rate in mgd	22.4	24.7	24.5	24.3	25.3	32.8	27.4	29.5	27.1	28.2	30.0	17.7
1951												
River	280	4270	6550	5030	11000							
Basin Effluent	200	1170	1840	1090	1450		(Both Old and New Basins in Use)					
Rate in mgd	24.1	24.8	23.6	23.8	24.6							
(2) Operation Through New Basins												
1952												
River	780	1180	3700	3870	4420	7220	11800	2530	3000	690	1450	480
*Basin Effluent	180	370	340	290	250	520	250	230	300	170	330	170
Rate in mgd	26.4	26.3	19.4	23.4	22.0	33.0	30.9	27.5	22.9	26.0	25.7	25.3
1953												
River	120	590	3400	4070	5370	6230	3000					
Basin Effluent	70	130	175	170	150	200	175					
Rate in mgd	21.8	24.9	25.8	26.0	27.0	33.4	33.6					

*Never over 600 for new basins

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